Logic Seminar, Winter 2015: Formal Semantics of Natural Language

1/13/15

Organizational

1. Seminar leaders: Solomon Feferman (feferman@stanford.edu) and Ivano Caponigro (ivano@ling.ucsd.edu)
2. Course Works W15-PHIL-391-01 (or W15-MATH-391-01)
3. Seminar website http://idiom.ucsd.edu/~ivano/LogicSeminar_15W/ (see for schedule, planned readings, background readings, and books on reserve)
4. *Call for Volunteers* !!
5. Special lecture: Barbara Partee, Tues. Feb. 24
6. Spring seminar: Quantifiers in natural language

Part I. The logical background to Montague's work (Feferman)

Montague's development

1. Richard Montague (1930-1971); PhD Philosophy UCB 1957 under the direction of Alfred Tarski; on UCLA faculty 1955-1971
2. (From Tarski) Style: extremely precise, Methodology: mathematical
3. Montague's work in logic, philosophy and formal semantics
4. The impact of Montague grammar (esp. PTQ)

The materials that Montague drew upon from mathematical logic

1. Syntax of formal languages (Frege, Russell & Whitehead, Hilbert)
2. Categorial syntax of natural language (Ajdukiewicz)
3. Models, satisfaction and truth in a model (Skolem, Tarski)
4. Typed λ-calculus (Church)
5. Intensionality, possible world semantics, modal logic (Frege, Carnap, Kripke)
6. Temporal logic (Prior)
7. Generalized quantifiers (Mostowski, Lindström)

Syntax of the predicate calculus with equality

1. Variables, constant symbols, function symbols; terms α, β, …
2. Predicate and relation symbols; atomic formulas $\alpha = \beta$, $R(\alpha,\dots)$
3. Formulas ϕ, ψ, …
4. Propositional operations, $\neg\phi$, $(\phi \vee \psi)$, $(\phi \wedge \psi)$, $(\phi \rightarrow \psi)$, $(\phi\leftrightarrow\psi)$
5. Quantifiers $\bigvee x\phi$ (or $\exists x\phi$), $\bigwedge x\phi$ (or $\forall x\phi$)
6. Sentences (= closed formulas)
7. Extension to many-sorted and higher type languages.

Models, satisfaction and truth

1. Structures $\mathfrak{A} = (A, R,\ldots,f,\ldots,c,\ldots)$
2. Assignments g: Var $\rightarrow$ A
3. Evaluation of terms, $\alpha^{\mathfrak{A},g}$ defined inductively
4. Compositionality: satisfaction of formulas $\mathfrak{A}, g \vDash \phi$ defined inductively; Montague writes $\phi^{\mathfrak{A},g} = 1$ just in case that holds, and = 0 otherwise
5. A sentence is true in $\mathfrak{A}$ just in case it is satisfied by some g (equivalently, all g).
6. Modifications for intensional and temporal logic: index structures by a set I, $\mathfrak{A}_i = (A, R_i,\ldots,f_i,\ldots,c_i,\ldots)$, and time by a set J. Thus write $\alpha^{\mathfrak{A},i,j,g}$ for $i \in I$ and $j \in J$, similarly for satisfaction of formulas

Functions, not sets! Function application and λ-abstraction

1. Motivated by functional view of categorial grammar
2. Given domains X and Y, Y^X is the set of all functions f: $X \rightarrow Y$, i.e., for any x, if $x \in X$ then $f(x) \in Y$
3. Subsets of a domain X are identified with characteristic functions in $\{0, 1\}^X$.
4. If $\alpha(x)$ is a term denoting elements of Y for each $x \in X$ then $\lambda x\alpha(x)$ denotes the function $f \in Y^X$ such that $f(x) = \alpha(x)$ for all x.
5. Example: Let X = Y = N, $\alpha(x) = x^2 + 3$; then $(\lambda x\alpha(x))(2) = 7$ and $(\lambda x\alpha(x))(3) = 12$

An aside: the untyped λ-calculus

1. Imagine a universe V of "all" things; then any f :$V \rightarrow V$ belongs to V
2. Let n be the function such that for any x, n(x) =1 if x(x) = 0, and n(x) = 0 otherwise; n can be written as $\lambda x\alpha(x)$ for suitable α
3. Then n(n) = 1 iff n(n) = 0, a contradiction (assuming 0, 1 are distinct)
4. But a formal version of untyped λ-calculus without n is consistent

The typed λ-calculus

1. Basic types e, t
2. If a, b are types then $\langle a, b\rangle$ is a type
3. Intended interpretation: for each type a, associate a domain D_a of objects of type a
4. Take $D_e = A$, $D_t = \{0, 1\}$
5. Take $D_{\langle a, b\rangle}$ to be the set of all functions f: $D_a \rightarrow D_b$
6. To deal with intensionality, Montague adds for each type a the type $\langle s, a\rangle$ or ^a with suitable interpretation $D_{\langle s, a\rangle}$; NB, there is no type s by itself
7. The set ME_a of meaningful expressions of type a is defined inductively
8. Then $\alpha^{\mathfrak{A},i,j,g}$ is defined inductively for α in ME.

Part II. The study of meaning in natural languages before Montague's work (Caponigro)

Within linguistics[1]

Little interest, little knowledge …

1. European linguists were mainly philologists who were mainly interested in historical and comparative investigation.
2. American linguistics came from anthropology and was mainly interested in field work.
3. The behaviorists viewed meaning as an unobservable aspect of language, not fit for scientific study, which influenced the American structuralists.
4. Quine had strong skepticism about the concept of meaning, and had some influence on Chomsky.
5. The great progress in semantics in logic and philosophy of language was relatively unknown to most linguists, who were at most familiar with first-order logic
6. In 1954, Yehoshua Bar-Hillel wrote an article in *Language* inviting cooperation between linguists and logicians.
7. Chomsky (1955) rebuffed Bar-Hillel's invitation.
8. Katz and Fodor (1963) and Katz and Postal (1964):
   - understanding a sentence is an ability to derive readings (ambiguity: more than one reading; anomaly: no reading; synonymy: same reading)
   - semantics is built out of dictionary of semantic markers and rules of composition
9. But David Lewis ("General semantics", 1970): "Semantic interpretation by means of [semantic markers] amounts merely to a translation algorithm from the object language to an auxiliary language [called] Markerese. […]Semantics with no treatment of truth conditions is not semantics."
10. Generative Semanticists, who were in part concerned with the interpretation of quantified sentences and the problems they created for Chomsky's notion of "Deep Structure", adopted a notion of "logical form" based on first-order logic.

[1] For more details see Partee, *On the history of the question of whether natural language is "illogical"*; link available on the seminar webpage, under "Readings – 1/13".

Within philosophy and logic

Natural language and logic are inherently different:

1. Much progress in the semantics of formal languages (see Part I of this handout)

2. Logic and natural language are different:

    a. "Formalists": natural language is vague and ambiguous, unsuitable for the foundations of science

    b. "Informalists": natural language can be used to do much more than conveying scientific truth

3. Paul Grice, *Logic and conversation*, 1967:

    "I wish […] to maintain that the common assumption […] that the divergences [between logic operators and their counterparts in natural language] do in fact exist is (broadly speaking) a common mistake, and that the mistake arises from inadequate attention to the nature and importance of the conditions governing conversation."

4. Richard Montague, *Universal Grammar*, 1970:

    "There is in my opinion no important theoretical difference between natural language and the artificial languages of logicians; indeed, I consider it possible to comprehend the syntax and semantics of both kinds of languages within a single natural and mathematically precise theory. […] No adequate and comprehensive semantical theory has yet been constructed and arguable that no comprehensive and semantically significant syntactical theory yet exists."